The doctrine of signatures depends on the notion that the appearance of plants signify their use. The eye-bright, on account of the eye-like spot in its corolla, is used for eyes; the granulated roots of the saxifrage indicate its use for calculous complaints; the human shape of the roots of ginseng give it special efficacy; and the walnut, the parts of which so closely resemble the skull and brain, is marked out for the mental diseases. The doctrine of sympathies has appeared under various forms, and has quite an important history. The common phrase, "Take a hair of the dog that bit you," is a survival of this system, and shows that the logic underlying it is nothing more than that two phenomena once connected, either by coincidence or as cause and effect, will continue to maintain this connection. Paracelsus describes a peculiarly composed weapon-salve which was to be applied to the weapon that caused the wound and thus heal the wound. Sir Kenelm Digby's practices involve the same notion. He procured a handkerchief or other personal belonging of the patient, and when this was dipped in water, the fever abated, and the like. The sympathetic alphabet was another form of this doctrine. Two friends each cut a piece of skin and grafted it on the skin of the other; on this was tattooed an alphabet, and communication was established by the belief that pricking a letter on the skin of the one friend would cause a pain in the corresponding place of the other. Even in the present century two Frenchmen announced the discovery of a species of snails which, however widely separated, would go through the same movements, so that if the one is guided over an alphabet the other will rest upon the same letters.

The most systematic of all these pseudo-sciences is astrology, the analogies underlying which being of all grades of remoteness. The system of correspondences which it proposed gave unusual opportunity for flights of imagination, and no analogy, however far-fetched, was too slight for the foundation of some doctrine. The accident by which the planets were given the names of deities was sufficient to connect the characters of those deities with the lives of persons at whose births these planets presented especial relations. Similarly the fact that constellations were named by fancied resemblances to certain animals was sufficient to connect one's career with the qualities of that animal; thus a child born under the sign of a lion would be courageous, but one born under the crab would not go forward in life.

Amongst the various generalizations upon which these considerations have bearing, attention will be called to the following. The history of the argument by analogy adds another link to the chain of evidence by which the development of the individual is connected with that of the race. We trace similar appearances amongst savages, amongst children, and still more strikingly in those surviving forms of superstition and pseudo-scientific systems which we are warranted in regarding as reversions to more primitive types of thought. Again, the principle that what was once the serious business of adults serves in more advanced stages of culture for the play of children or the amusement of leisure hours, finds illustration here. Just as the drum, once the terrifying instrument of the warrior, or the rattle, once the potent implement of the medicine-man, has become the toy of children, or as the bow and arrow are maintained for sport only, so the outgrown forms of thought, the analogies, that were serious to our ancestors, now find application in riddles and puns. When we ask, "Why is this one object like another?" we are asking for just such out-of-the-way resemblances as have been noted above. And, finally, in a variety of ways, the consideration of the argument by analogy adds to our appreciation of the unfoldment of mental powers, of the slow and painful steps by which the tenets of modern science have been gained, of the necessity for continued striving in this direction, as well as of the underlying unity of movement and design by which these phenomena acquire their deeper and more human interest.

THE ETHER.[1]

IT was with some fear and trembling that I selected as the subject of a brief address a subject of such vast dimensions, and the feeling increased as it became more and more evident how difficult it is to give clear expression to ideas that are very far from clear.

In former days many reasons were given showing the necessity for the existence of an ether which do not seem conclusive now. We can scarcely appreciate the bearing of an argument to the effect that there must be an ether or nature would be disgusted with the major portion of space. We should begin at once to wonder what there could have been in the experience or training of any person that could lead him to such a conclusion. We do not see the need of an ether to hold up the stars and planets and prevent them from falling to the ground. We do not try to explain by similar means how the planets are kept in motion.

We do, however, have other needs for ether, which seem important and pressing; still we cannot help wondering occasionally, with Theophrastus Such, what kind of hornpipe we are dancing now. How will our ideas commend themselves to those who follow?

For many years it was taught that the luminiferous ether was an incompressible jelly-like mass, and that light is an elastic pulsation in this medium. The elastic theory, however, was burdened with serious difficulty. No phenomena corresponding to a vibration normal to the wave front could be found, but mathematical analysis showed that such waves should in general exist in an elastic medium. Green saw that this wave would produce no optical phenomena if the velocity were either zero or infinite, and concluded that it could not be zero in a stable medium. Those who followed him in time also accepted his conclusion that the ether was incompressible, and that the compression-rarefaction wave must travel with an infinite speed. So the matter stood until 1865, when Maxwell proposed an electro-magnetic theory of light. According to this theory of light no compression-rarefaction wave should exist, and light was conceived to consist of local electrical displacement in a plane at right-angles to the line of propagation.

The rival theory met with great favor. It gradually became clear that Maxwell's theory of light was attended with less difficulty than the elastic theory. Twenty-three years later, Sir William Thomson brings a powerful reinforcement to the elastic theory which changes the whole aspect of the case. He simply suggests that the compression-rarefaction wave could properly and logically be gotten rid of in the elastic theory by making its velocity zero, instead of infinite, as Green had done half a century before. What Thomson did was to examine anew the ground upon which Green had concluded that a zero velocity for the compression wave involved an unstable state of the medium, and it was found that such a conclusion did not follow.

[1] Abstract of an address before the Section of Physics of the American Association for the Advancement of Science, at Washington, D.C., Aug. 19-25, 1891, by Francis E. Nipher, vice-president of the section.

And it is worthy of remark, as a matter of congratulation, showing how far scientific men have emerged from the intellectual pugilism of the last century, that this audacious departure was met with pleased surprise, instead of angry polemics against a new heresy.

The modern theory of the ether took its origin with the undulatory theory of light. It had for a tangible basis the observed fact that light requires time for transmission. Whether measured over long distances through interplanetary spaces, or through short distances on the surface of the earth, the time required for transmission is proportionate to the distance. It was to such facts that men finally came to look for a justification of the assumption of an all-pervading medium. The modern theories of the nature of the ether are based wholly on the results which must be produced by this invisible machinery, instead of upon an assumed dictum that Nature abhors a vacuum. Perhaps no teaching of science is now more firmly established than the doctrine of the existence of an ether, and that it is capable of transmitting energy by virtue of peculiarities which must be as definite as those which characterize a train of cog-wheels.

But when one comes to assemble all of the results which remain to be accounted for and explained, it becomes exceedingly difficult to construct a mental image, in three-dimensional space, of the machinery capable of producing them all.

Green's idea of the ether makes it an incompressible, frictionless, structureless jelly, sometimes called a "solid," which opens out and allows the particles of ordinary matter to sweep through without appreciable resistance. Thomas Young likened the operation to the sweeping of the wind through the leaves and branches of a forest. Certain well-known electrical experiments of Faraday and Cavendish seem to require the assumption that electricity is, or is some function of, an incompressible medium. On the other hand, the slowing up of light in space occupied by matter indicates that the ether within must be either more dense (as Fresnel believed) or less elastic than that existing in free space. It is certainly very difficult to understand what there can be in the molecules of matter which can increase the density of an incompressible medium, as the experiments of Fresnel seemed to require; nor is it as yet easy on any hypothesis to account for those condensed films of bound ether which are carried along with the particles of moving matter. They seem to be differentiated with equal sharpness from the free ether which sweeps through matter, and from the spinning aggregation of ether vortices which Thomson assumes may perhaps make up the molecule or the atom. Certainly it would seem that a vortex ring in a medium so devoid of friction that these vortices are permanent, could hardly drag along with it portions of the surrounding medium, from which the analysis of Helmholtz shows it must be wholly and forever differentiated. And the matter is not simplified by the beautiful experiment of Michelson and Morley. It appears that the frictionless ether adheres in a layer around the earth as a whole, or at least that it was entangled in and carried along with the matter composing the building in which their experiments were made.

If, however, one forms a Torricellian vacuum in a barometer tube of either transparent or opaque material, it is easily and completely shown, by an inclination of the tube, that the ether flows freely through matter. Whether the ether be incompressible or highly compressible, it seems to be as impossible to compress it in a chamber surrounded by matter as it would be to compress water or air in a fisher's net. The fact that a rotational phenomenon, such as must exist in the field of a steel magnet, is maintained indefinitely without the expenditure of energy, must certainly justify the assumption that the ether is frictionless, that the ether-vortex atom is a possibility.

The effects which seem to be nearest to a mechanical explanation are those which result in heat or light and electrical and magnetic induction. It is possible to construct machinery which will represent the conditions for propagation of a magnetic induction in a plane radial to a conducting wire. A train of cog-wheels separated by elastic idle-wheels which articulate with them, or a series of smooth rimmed fly wheels connected by elastic bands, will do the work. It becomes more difficult when we spread this paraphernalia into three-dimensional space.

No one, of course, thinks of the geared ether models of Maxwell and Fitzgerald as anything more than an aid to a conception of the nature of the action to be explained. When we come down to the working drawings we find great room for conjecture, and some demand for invention. Do the particular cog-wheels which slip on each other without friction at the surface and within the body of a perfect conductor ever get outside of the body into free space where they must gear rigidly with each other? If so, why do they behave so differently in the two places? What happens to this gearing when masses of matter which it permeates are set into rotation? Is there any difference between the earth's magnetism and the motion of masses of ether at the earth's surface? It is exceedingly difficult to understand how a frictionless medium in which a magnetic spin is permanent, can offer resistance to shear, unless the rigidity involved is due to motion.

Another function which the ether should perform is the transmission of gravitation. The theory which has attracted most attention, the only one suggested which has been seriously considered, is the one first announced by La Sage of Geneva, and elaborated by Preston and others. It seems to require that the ether shall partake of the nature of the gas, the mean free path being of interplanetary dimensions.

Such a medium it is not difficult to admit as a possibility. The theory accounts for the gravitation of bodies towards each other as due to the difference in the bombardment of bodies on the exposed and sheltered sides. Each body shields the other, so that gravitating bodies are pushed together. It is, however, necessary that the particles at the centre of the earth shall have the same resultant differential pressure directly exerted upon them, causing them to gravitate towards the sun, as if the surrounding mass of the earth were removed. It is, in fact, necessary to assume that nearly all the ether particles which plunge into the earth's figure pass straight through the earth without encounter with matter.

It is, however, of some interest to know quantitatively about what velocities must be involved in such an impact theory of gravitation. DeVolson Wood has made a computation of the density of an elastic medium capable of transmitting a pulsation with the velocity of light, and of transmitting from the sun to the earth 2.8 calories per minute per square centimetre of surface. While it seems to me that some fault may be found with his analysis, still the results reached by him seem to be of the proper order of magnitude.

The density of the ether turns out to be about $\frac{2.6}{10^{24}}$ pounds per cubic foot, so that a mass equal in volume to that of the earth would contain about a pound and seven-tenths. This value for density lies well within the limits which Sir William Thomson assigned to the same quantity.

Suppose a stream of ether of such material should sweep radially sunward, its particles colliding in unelastic impact with the earth, what velocity must be given to this current in order that the earth might be kept in its present orbit? The velocity turns out to be eight millions of times the velocity of light. The mass of ether colliding per second would be 14,000 tons, which is equal to the mass of a sphere of water having a radius of about fifty feet.

But in LeSage's hypothesis the ether particles do not move in parallel stream-lines. They plunge into the earth on all sides, the sheltering effect of each gravitating body upon the other being the cause of gravitation. But this sheltering effect is very small, by reason of the open structure that matter must be assumed to have in order that the interior particles of large masses may be accessible to direct impact. It follows that the percentage of particles really effective in producing gravitation must be very small; likewise that the individual particle velocities must enormously exceed the velocity computed for a stream of ether sweeping radially sunward and capable of holding the earth in its orbit.

It is unphilosophical to condemn the theory of LeSage because it requires us to deal with such immense velocities. Any theory of gravitation must involve something unusual, and it was pointed out by Laplace that the velocity of gravitation must enormously exceed that of light. But there are other difficulties.

The rebound of the particles must be a perfectly elastic collision; otherwise the bombarded body will rise in temperature. By reason of the open structure assumed and necessary, in order that the effective surface may be proportional to mass, the exterior figure is of no importance. For simplicity of conception, if we assume a solitary sphere in space, it will be symmetrically beaten from all sides. The particles which pass straight through, without deflection or elastic rebound, will be symmetrical all around, as will likewise the few which suffer reflection. A second body now appearing in its field will shield the first by deflecting particles which would otherwise strike it, but will reflect to the body an equal number which would otherwise not strike it, the latter group having the same average momentum as the former.

Sir William Thomson has suggested that the difficulty may be avoided by assuming that the collision is not a perfectly elastic one, and that the rise in temperature may be prevented by rotation of the colliding particles. This might be true of the ether particles, but there is the best of reason for believing that there is no molecular rotation in solid bodies.

It seems probable, therefore, that a rebound sufficiently unelastic to account for gravitation must result in a rise of temperature, which can scarcely be admitted. The theory has, however, been defended with great skill by Preston, who has attempted to show that such a medium may even produce the transverse vibrations of light. The objection that gravitation must travel at enormously greater speed than light he tries to meet by the hypothesis that the gaseous ether may have two groups of particles, one much larger than the other. The properties of the luminiferous ether have, however, been so well worked out in the last four or five years, that it seems hardly probable that the gaseous ether can be admitted as the medium which transmits light. Whether gravitation can or cannot be explained in some such way as LeSage suggested, it seems worthy of question whether the gravitation medium can be ether which transmits radiant energy with a velocity of 300,000,000 of metres per second. Sir William Thomson's last word on the elastic solid theory of ether, according to which the compression wave is impossible by reason of a property which is imparted to the medium, seems to cut off the last hope that the elastic solid luminiferous ether can be concerned in gravitation. The electric theory of light does not require Sir William Thomson's limitation to be put upon the medium. According to this theory the medium may be incompressible, and there is strong reason to believe that it is practically so. As Willard Gibbs has pointed out, the two theories seem to be practically on the same footing, if the third wave is given an infinite velocity in the electric theory, and zero velocity in the elastic solid theory.

There are other points concerning the action of matter upon the ether which are perhaps in a fair way to receive a clearer solution. The observed fact that light travels in water with a speed of about three-fourths of what it has in air, apparently means that the transmitting medium is either more dense or less rigid in water than in air. Fresnel's hypothesis is that its rigidity is the same in the two media. His formula, as developed by Eisenlohr, for the relative motion of ether and matter which it permeates, when the matter is set into motion, assumes, clearly and baldly, that the ether is more dense inside of matter than in free space. The amount of ether occupying a volume of one cubic centimetre will condense to nine-sixteenths of a centimetre on passing into water. It is compressed until its density is nearly double. To be more accurate, its density increases by seven-ninths of itself upon passing into water. Of course this is to be regarded as a mathematical fiction serving to bridge over a gap in our knowledge of the physics of the ether. Certainly a medium behaving in this manner would not be considered to be a shining success as an incompressible medium. Fresnel's conclusion rests mainly on an experiment first made by him and repeated with great success in an improved form by Michelson and Morley. This experiment was to determine the effect of moving water upon the velocity of light transmitted along its stream-lines. The result reached was that the resultant velocity of light is its velocity in the quiescent liquid plus or minus seven-sixteenths of the velocity of the moving liquid.

The velocity of the water current was varied between 8.72 metres and 5.67 metres per second, in Michelson and Morley's experiment. A series was made with an intermediate velocity of 7.65 metres per second. The weights of the three determinations are quite different, and it appears to be still an open question whether the result obtained is independent of the velocity of the water. In Eisenlohr's analysis he assumes a prism of matter moving bodily through a mass of quiescent ether. In Michelson and Morley's experiment the water was fed from an upper to a lower tank, passing on its way through the experimental tubes. The conditions of the two experiments do not seem to be necessarily the same. The bounding surface between air and water is moving with a very small velocity in the apparatus of Michelson and Morley, and the observations are made through a fixed region of space. It is not clear that this difference is of importance, but it seems possible that it may be, in determining the effects for different velocities.

The close agreement between the observed value of the velocity coefficient for the moving ether and the value computed on the assumption of an actual condensation of the ether, is, of course, a very worthy consideration. Still it seems very improbable that such a condensation can really take place. The ether may lag behind the moving water

without any condensation, and the other phenomenon requiring a greater density in matter than exists in free space, may, perhaps, receive other explanations that do less violence to our ideas. Ether, in which the complex molecules of matter are entangled, certainly might act as if it were more dense without really being so.

What the experiment of Michelson and Morley seems to show is that the ether is swept along by the water, but lags behind. The question of density appears to me still to be an open one. Maxwell's experiment with a prism which was, as was then supposed, moving through ether at a speed of 18.6 miles per second, seems to have a very different relation to Fresnel's theory if the ether at the earth's surface is moving with it.

It does not seem hopeless to repeat the experiment of Michelson and Morley on a railway coach, with water or carbon bisulphide at rest in the tube, if the road-bed and the car selected are of the best construction, and the apparatus is elastically supported.

It would be necessary, probably, to rigidly connect the observer's seat and the water tube, and to support them, with the observer, by helical steel springs surrounded by rubber tubes filled with glycerine to dampen the vibrations.

A speed of forty miles per hour will more than compensate for the suppression of one water column, which will be replaced by air. This is precisely the form of experiment upon which Eisenlohr's analysis is based. In this form the conditions of the experiment are capable of great variation. The car becomes really the moving body, and the transparent region within through which the light passes, may be shielded by any kind of opaque matter. Whatever the results may be, they can hardly fail to add greatly to our knowledge of the effect of moving masses upon the luminiferous ether.

LETTERS TO THE EDITOR.

*** *Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

On request in advance, one hundred copies of the number containing his communication will be furnished free to any correspondent.

The editor will be glad to publish any queries consonant with the character of the journal.

Jugglery.

IN *Science* for Aug. 14 there was an inquiry, quoted from *Illustrated News of the World*, as to the source of a certain statement regarding the apparently marvellous feats of Indian jugglers. In this statement it had been suggested that the spectators had been hypnotized by the performer, and hence imagined they saw something which the "snap-shot" of a kodak proved did not exist at all. I remember reading this very circumstantial account in an evening paper, and cut it out to send to India. After some search I have found the original reference. The story, as a quotation from the Chicago *Tribune*, was published in the *Evening Star* of Washington, D.C., on Aug. 30, 1890. Its author, Frederick S. Ellmore, purported to be a graduate of Yale College, and to have travelled extensively in India with an artist friend, a Mr. Lessing. It has since transpired that no person by this name is a graduate of Yale.

To my mind the story shows a good many signs of being on the Mulhatton style, and could easily have been written by some one who had never been in India. It is very plain that no juggler could by any possibility hypnotize a mixed audience all the time changing. Those who have seen the original growth of the mango-tree under the manipulations of the performer, who was stark naked except for a *lungooti* (breech cloth), will be inclined to smile at Hermann's explanation given in *Science*. My father has spent twenty years in India, and has seen this performance repeatedly. He has noted one singular coincidence, in that the tree is never made to grow except in the season when the leaves and fruit of the mango-tree are in proper order for the exhibition.

H. A. HAZEN.

Washington, D.C., Aug. 18.

The Rain-Makers.

EVERY reader of *Science* has seen the recent telegram from Midland, Texas, Aug. 11, "Preliminary explosions made yesterday; raining to-day." It may be well, with the apparent brilliant success of this remarkable undertaking before us, to examine this question at length.

Ever since the time of Plutarch the idea has been prevalent that great battles are invariably followed by rain. In the earliest times, before the introduction of gunpowder, it was thought that exhalations from the dead bodies might assist in precipitating the moisture, but in more recent times there has been a well-nigh universal belief among soldiers that heavy cannonading or firing will produce rainfall. Whence comes this common thought were there not a fact to originate and back it up? We may as well ask, whence comes the well-nigh universal belief that the moon has a marked influence upon the weather? Now it is well known that in the latter case, most careful researches extending over a century have shown either no effect at all, or one that was either contradictory in different periods, or almost inappreciable.

Now since the moon's influence must be almost infinitesimal, as every one can readily see, it would be difficult, perhaps, to determine its exact relation to weather changes which are so complex, but it would seem far otherwise as to the determination of the exact effect of explosions upon the atmosphere. A careful study of this question has been made by Mr Edward Powers, who has found that 158 of the smaller and larger battles of the Rebellion were followed by rain, usually twenty-four hours afterward. It might be asked, is it possible that this list comprises all the cases? While some of the battles may have been omitted, yet it seems highly probable that a diligent search must have revealed most if not all there were. It is a most remarkable fact that no mention whatever is made of the battles that were not followed by rain, and yet in an inquiry of this kind it is very essential to examine both sides of the question. During the war of the Rebellion there were over 2,200 battles, on an average probably as severe as the average of the 158 above mentioned; that is to say, about seven per cent of the battles were followed by rain. Is it at all incredible that seven per cent of these battles were followed by natural rain? In the case of the battle of Bull Run, which Mr. Powers especially picks out as a bright and shining example of his theory that explosions produce rain, it has been ascertained that there was a heavy rain in South Carolina on the first day of the battle. This rain had been previously noted farther south, and this was the rain felt at Bull Run. It would be very interesting to look up the question of how many of these 158 apparent successes were due to natural causes, but unquestionably almost all, if not all, may be ascribed to that cause. It is interesting to note that it is thought this influence may extend twenty-four hours after the explosions cease. This inference, however, is hardly tenable, for the reason that the current in which these explosions take place is borne along at the rate of 20, and, in higher strata, at 30, 40, 50, and more, miles per hour, so that the specific influence from them will be carried at least 500 miles away in twenty-four hours. If we wished to determine the effect, we would need to go to that distance from the spot where the explosions were made, and the rain that came in twenty-four hours at that spot could not by any possibility be due to the explosions.

There is only one other point to be noted here. It has been stated that while the Central Pacific Railroad was being built across the Sierra Nevada Mountains, it was necessary to explode hundreds of kegs of gunpowder every day, and this tremendous fusillade was accompanied by torrents of rain, which had never been noted before in that region, and have not been noted since. If this is a fact, it was a most remarkable phenomenon, and it would seem as though it might be established by indubitable evidence. It is a little singular that no dates or definite statements which could be verified have been given. Present rainfall reports show an abundance of rain except in two or three of the hottest months, and it seems entirely probable that persons who had been accustomed to the remarkable and long continued dryness of the plains were struck by what appeared like most abundant moisture in the mountains just at a time when there was none on the plain.